4 Characterization of the Ozone Weekend Effect in California

4.1 The Weekday-Weekend Behavior of Ambient Ozone Concentrations in California

This chapter is being written. It will summarize the Austin & Tran 1999 paper, "A characterization of weekday-weekend ambient ozone concentrations in California," Proceedings of the 7th International Conference on Air Pollution, July 27-29, Palo Alto, California. The paper is presently on the Web and will be included as an appendix to this chapter.

APPENDIX to Section 4.1

A characterization of the weekday-weekend behavior of ambient ozone concentrations in California

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Abstract

Since the 1970's, air quality studies have shown that ozone concentrations increase on weekends at many locations. Most of these studies have focused on a specific region, and many of the studies have used simple statistical approaches which fail to yield conclusive evidence in the presence of strong random noise. We analyze day-to-day changes in daily peak ozone concentrations for three major urban areas in California using a more precise statistical approach, estimating percentage changes from day to day and examining spatial patterns among sites. We filter out trend and seasonality, explicitly account for serial dependency, and use robust statistics to reduce the effect of outliers. We find that many sites in all three areas exhibit a characteristic "weekend effect", but some sites show different patterns or fail to display a statistically significant pattern. Many sites show a "Sunday effect" in the 1996-98 period. Similar spatial patterns prevail in all three regions.

1 Introduction

Several studies have documented the phenomenon of higher ozone concentrations on weekends in California. This so-called "weekend effect" has aroused strong interest because of its potential implications for ozone control strategies. In the 1970's, Elkus and Wilson[7], Horie *et. al*.[8], and Levitt and Chock[10] found evidence for elevated ozone concentrations on weekend days at some locations in Southern California. Analyses by Zeldin *et al*.[12] and Altshuler *et al.*[1], based on more recent data, show that ozone concentrations continue to be higher on weekends, although ozone concentrations have decreased steadily over the last two decades in most areas of the state.[4]

Evidence from other parts of the United States is conflicting, some areas exhibiting lower ozone values on weekdays, some failing to display a significant difference between days of the week, and others behaving similarly to Southern California. [1, 6, 9]

Most, if not all, previous studies have been limited to a single geographic area or a handful of scattered sites in several areas, so it has not been possible to make inter-regional comparisons with a single, consistent methodology. While a few studies, notably Horie *et al.*[8], have taken a more sophisticated statistical approach, most studies have been based on simple measures such as the number of hours above a regulatory standard concentration or mean peak concentration by day of week. Such techniques are relatively insensitive and do not fully take into account the statistical properties of the data. They do not yield precise estimates of the day-to-day changes in ozone concentration, and they may fail to detect subtle patterns against a background of strong random noise.

The goal of this study is to accurately characterize the weekend effect in three major urban regions of California: Los Angeles, the San Francisco Bay Area, and Sacramento. The analysis is based on differences between consecutive or "sibling" days rather than differences between average concentrations, and therefore yields more precise estimates. We use analytical techniques tailored to the special characteristics of the data, explicitly considering trend and seasonality, serial dependence, and outliers. The improved accuracy leads to a more reliable assessment of statistical significance. We use principal component analysis to examine spatial patterns among sites in each of the three regions, which reveals patterns which are otherwise not readily apparent. Section 4 presents a qualitative assessment of the results; numerical estimates of day-to-day differences for specific sites are tabulated at the end of this paper.

2 Data

We examined daily maximum one-hour average ozone concentrations at each site during the high ozone period, May 17 through October 15, from 1992 to 1998. Data were taken from the Air Resources Board ADAM air quality database.[3] Due to the impact of the federal reformulated gasoline (RFG) and California cleaner-burning gasoline (CBG), we looked at the results for two separate periods, as shown below. RFG was introduced in Los Angeles beginning in the Spring of 1995, and CBG was introduced statewide in the Spring of 1996. Data for 1995 was excluded for Los Angeles because, as a transition year, it was not expected to be representative of either period.

	Pre-CBG	**Post-CBG**
Los Angeles	1992-94	1996-98
San Francisco Bay Area	1992-95	1996-98
Sacramento	1992-95	1996-98

3 Methodology

To characterize the variation in ozone concentrations over the week, we computed the average shift from one day of the week to the next. Since the magnitude of the systematic shift based on the day of the week is modest compared with the random variation from one day to the next, we tested whether the differences are statistically significant. Based on these average differences, we examined the sites in each geographic region as a group, to see whether sites that share topographical, meteorological, or emission characteristics show similar patterns of ozone changes throughout the week. We did not consider precursor or meteorological data in this study; we focused solely on ozone behavior. In the next few paragraphs we describe the specific steps in the analysis in greater detail.

3.1 Serial Dependence

One of the key features of air quality data is serial dependence. Owing to the atmospheric persistence of ozone and its precursors, and the tendency for meteorological factors in ozone behavior to be similar from one day to the next, peak ozone concentration is generally similar from one day to the next. Consequently, sequential differences between peak ozone will be correlated to some degree. To account for serial dependence, we examined only differences involving weekend days; i.e., we computed differences between Friday and Saturday, Saturday and Sunday, and Sunday and Monday, ending up with three differences for each week. Figure 1 shows the autocorrelation of ozone daily maxima, adjusted for trend and seasonality, for Azusa, east of downtown Los Angeles (the autocorrelation is a measure of the correlation between each daily maximum and those on nearby days, as a function of the number of intervening days; see, for example, Brockwell and Davis[2]). As Figure 1 shows, the correlation drops off rapidly, so the correlation between a Monday and the succeeding Friday is essentially zero. We can therefore treat the triplets of differences as statistically independent. Later, we use a multivariate technique to compute the means of the three differences that explicitly takes into account the correlations among weekend days.

3.2 Isolating the Weekend Effect from Other Sources of Variation

A series of daily ozone measurements exhibits several kinds of systematic variation, including meteorology, trend, and any day-of-week effect which may be present. We therefore took measures to filter out variation caused by factors other than the weekend effect and isolate the signal of interest. Figure 2 shows a series of daily peak one-hour average ozone concentrations measured at Azusa between 1994 and 1997, bracketing part of both study periods. The graph shows the characteristic seasonal ozone cycle, with high concentrations in summer months and low concentrations in winter. The graph also shows that ozone concentrations are more variable in the summer months; i.e., the variability scales with the concentration.

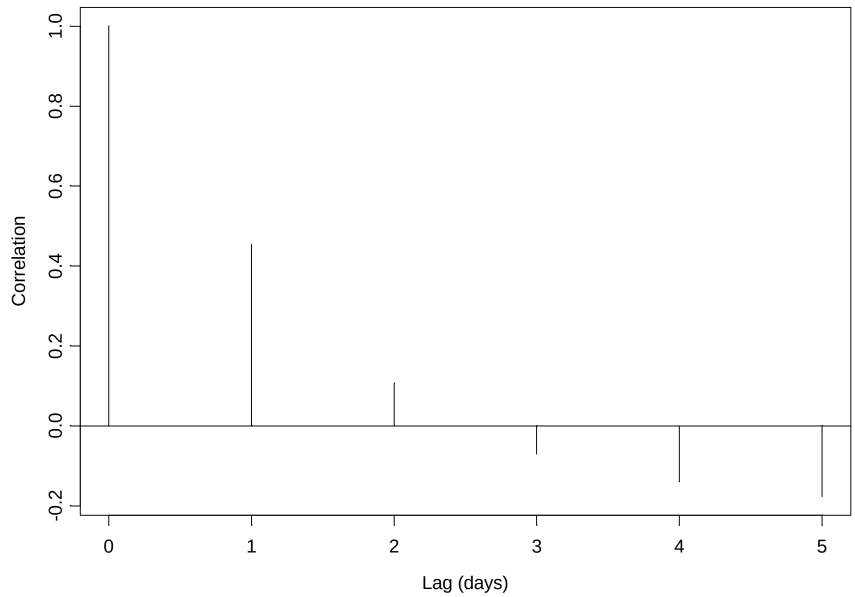

Figure 1: The estimated autocorrelation function of daily peak ozone concentration at Azusa, 1992-98. Note that the correlation falls off rapidly after a few days.

There appears to be a downward trend or shift, at least within the time period displayed, with summer concentrations distinctly lower in the later two years than in the first two, probably owing to the introduction of CBG in 1996 and to an El Niño event during 1997-98. A weekend effect, if present, would appear as a periodic pattern embedded within all this variation. To isolate it, we applied several signal processing steps:

(i) Logarithmic transformation. By taking natural logarithms of the original ozone concentrations, we render the variability approximately constant over time and independent of the ozone concentrations.

(ii) Smoothing and residuals. We applied a smoothing filter to the log transformed concentrations. The output of the filter is a weighted moving average of the log transformed concentrations, where the weights assigned to each group of 29 values taper off to either side. In time-series terminology, we applied a moving average filter (see Brockwell and Davis[2])

$$y_t = \sum_{|i|<k} w_i x_{t+i}$$

where the weights are the triangular series

$$w_i = \begin{cases} \dfrac{k-|i|}{\sum_{|i|<k}(k-|i|)} & \text{if} \quad |i|<k \\ 0 \quad \text{if} \quad |i| \geq k \end{cases}$$

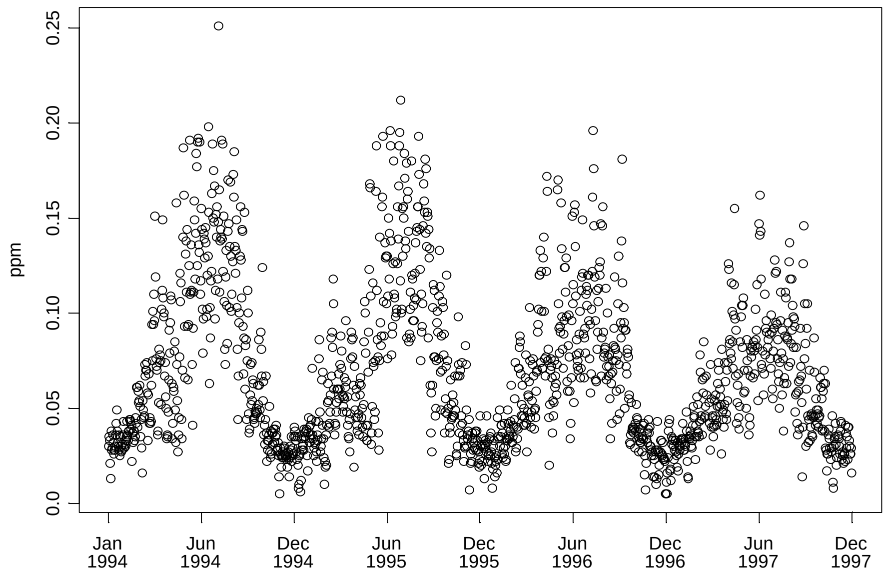

Figure 2: Daily peak ozone concentration, Azusa, 1994-97.

and *k* was chosen to be 15, a compromise value which preserves the high frequency component of signal without introducing excessive bias. The result is a smoothed version of the input series, which preserves the seasonality and trend components in the data but smooths out the day-to-day variation. We subtracted this smoothed series from the log-transformed concentrations to obtain "adjusted daily peak ozone concentrations". Steps (i) and (ii) comprise the adjustment for trend and seasonality alluded to above. The log-transformed ozone concentrations and smoothed series are shown in Figure 3.

3.3 Restriction to Summer Weekends

At this stage, we restricted the data to summer weekends (Friday through Monday, May 17 through October 15), removed weekends on which a major holiday fell (Memorial Day, Independence Day, Labor Day), and computed successive differences from one day of the week to the next. We ended up with three differences for each site, for each week of the study period. As a rough check, we also computed univariate means of midweek differences, Tuesday-Monday through Friday-Thursday, and their standard errors. None proved significant at the 95% confidence level, for any site in any area, for either study period.

3.4 Robust Estimation of Means

We can think of individual differences as being the sum of two components: the periodic signal we are interested in, and "noise". If the noise component is random and symmetrically distributed, the arithmetic averages of the differences should provide a good estimate of the periodic signal.

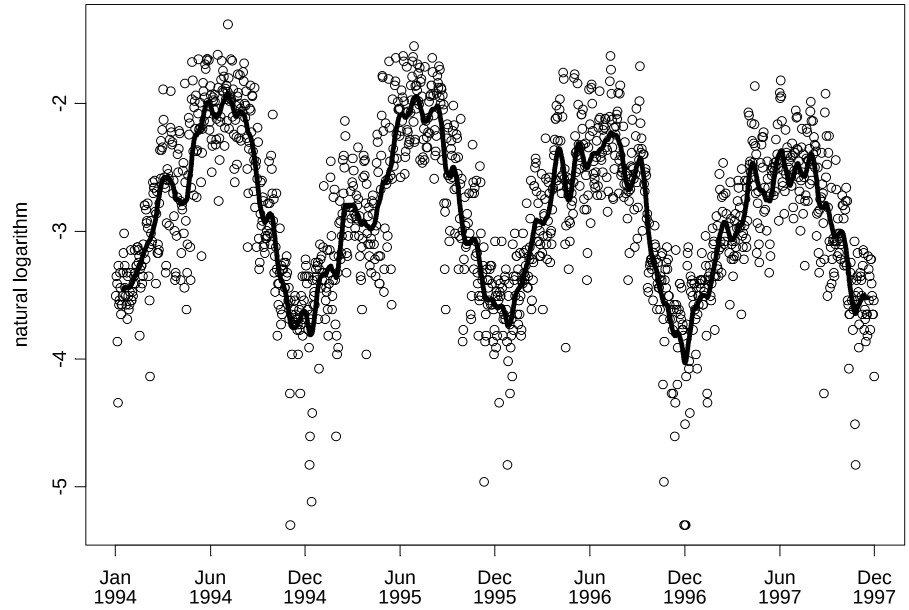

Figure 3: Natural logarithm of daily maximum ozone concentration, Azusa, 1994-97. The smoothed series is superimposed as a dark line.

However, as Figure 4 suggests, while the bulk of the data are distributed roughly in a normal, bell-shaped distribution in two dimensions, the data include occasional outlying values which can have a large influence on the mean concentration. Accordingly, rather than simply taking arithmetic means, we used a robust technique described in Campbell[5], designed to reduce the effect of outliers. The technique involves iteratively computing a weighted covariance matrix and mean (treating the three differences for each week as a vector $\mathbf{x}_i$)

$$\bar{\mathbf{x}}_M = \sum_{i=1}^{n} w_i \mathbf{x}_i \Big/ \sum_{i=1}^{n} w_i \qquad \mathbf{S}_M = \sum_{i=1}^{n} w_i^2 (\mathbf{x}_i - \bar{\mathbf{x}}_M)(\mathbf{x}_i - \bar{\mathbf{x}}_M)' \Big/ \left(\sum_{i=1}^{n} w_i^2 - 1 \right)$$

where the weights are given by

$$w_i(d_i) = \begin{cases} d & \text{if} \quad d \le d_0 \\ d_0 \exp\{-\tfrac{1}{2}(d-d_0)^2 / b\} & \text{if} \quad d > d_0 \end{cases}$$

and d_i is the Mahalanobis distance

$$\{(\mathbf{x}_i - \bar{\mathbf{x}}_M)'\mathbf{S}_M^{-1}(\mathbf{x}_i - \bar{\mathbf{x}}_M)\}^{\frac{1}{2}}$$

Following Campbell[5], we reparameterized d_0 as $(\sqrt{3} + a / \sqrt{2})$, and took $a = 1.96$, $b = 1$, to down-weight roughly the outlying 5% of the data, assuming normality. With approximately $n \approx 60$ data points for each site, the vector of means has approximately a multivariate normal distribution with covariance matrix $n^{-1}\mathbf{S}_M$.

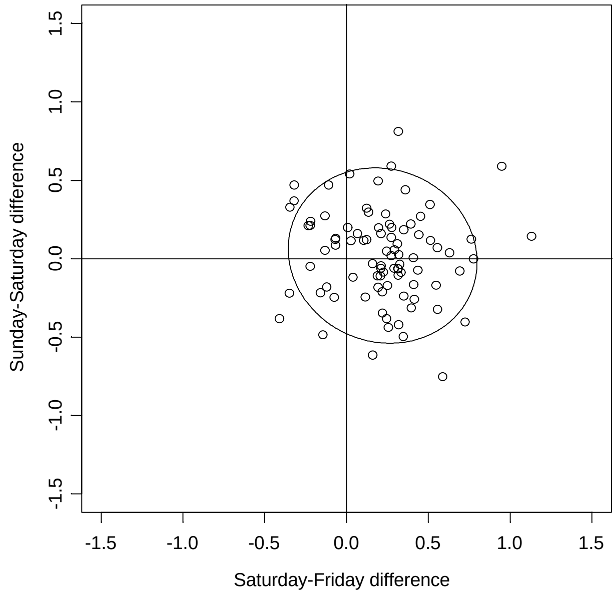

Figure 4: Scatter plot of Sunday-Saturday vs. Saturday-Friday differences for Azusa, 1994-97. The ellipse, in this case nearly circular, includes roughly the inner 95% of the data points for a normal distribution.

We tested the significance of each individual mean difference, taking the variances from the diagonal of the covariance matrix. The results are also shown in Table 2. Although the robust technique we used down-weights outlying values conservatively, it has a tendency to underestimate the magnitudes of the variances and covariances. Therefore, there is a slight tendency to overestimate the significance level of the differences. Also note that the 95% level of significance stated in Table 2 applies to *each* individual difference; it is not a simultaneous confidence level for the entire set of differences.

3.5 Descriptive Statistics

In Table 2 we report average percent changes. These are computed from the robust mean differences x by applying the transform

$$y = \exp(x) - 1$$

We also report absolute differences, which are extrapolated from the mean Friday ozone using the percent changes computed above. These are intended merely to serve as a convenient standard for comparison and not as rigorous estimates, since our methods optimized the estimation of percent changes rather than absolute differences.

3.6 Principal Component Analysis

To facilitate interpretation of the spatial patterns among sites, we performed a separate principal component analysis (PCA) on each geographical region (see, for example, Rencher[11]). Treating the robust mean differences for each site as defining coordinates in three-dimensional space, PCA effectively rotates the coordinate axes in space so as to explain most of the variability in the data with the smallest number of variables. In the case of the average differences, three-dimensional plots clearly showed that for each region, the differences lay in a thin plane in three-dimensional space. Accordingly, we can use PCA to find a new set of coordinate axes lying within the plane of the data, and describe most of the variation in the data using only two variables. The results are useful as a visual tool, as they make clear which sites are behaving similarly, and what changes took place between the two periods. Figures 6 through 8 show plots of the data for the three regions in the transformed coordinate system. Mathematically, the principal components are linear combinations of the original coordinates. Table 1 expresses the principal components for each region as a linear combination of the robust mean differences.

4 Results and Discussion

Table 2 presents mean Friday maximum ozone concentrations, day to day changes in percent and absolute concentrations, and an indication of whether the percent changes are significant at the 95% confidence level.

In general, the percent changes from Friday to Saturday and from Sunday to Monday are significant for Los Angeles and the San Francisco Bay Area, but not for Sacramento. Since there are fewer sites in Sacramento, and many sites lack a substantial fraction of the data, we will focus our discussion on Los Angeles and the San Francisco Bay Area.

4.1 Los Angeles

During 1992-94, the typical pattern for ozone in many sites in Los Angeles is a large increase from Friday to Saturday, no change or a small decrease from Saturday to Sunday, then a large decrease from Sunday to Monday. This "weekend effect" is strongest at downtown sites and least pronounced at transport sites far downwind. For example, at the Los Angeles-North Main Street site (LA), adjusted daily maximum ozone increased 31% from Friday to Saturday, increased slightly (1%) on Sunday, then decreased 28% on Monday. Lynwood, Pasadena, and Pico Rivera, near Los Angeles, share a similar pattern. Further downwind, at Azusa, Glendora, and Pomona, the effect is not as strong; however, the Friday to Saturday and Sunday to Monday changes are statistically significant.

Generally speaking, the further downwind a site is, the milder the weekend effect. At the downwind extreme, Lake Gregory, Banning, Hemet, Perris and Santa Clarita show a relatively small weekend effect. In the 1992-94 period; the Friday to Saturday and Sunday to Monday changes are not significant. Lake Gregory actually displays a slight increase from Sunday to Monday. In fact, in the early period, Lake Gregory, Banning, and Hemet are characterized by a pattern of ozone behavior different from the "typical" weekday effect: a Friday to Saturday increase, a Saturday to Sunday decrease, and relatively little change from Sunday to Monday. However, in 1996-98, Lake Gregory shows a more typical weekend effect: a statistically significant increase from Friday to Saturday, and a significant decrease from Sunday to Monday. Banning, Hemet and Perris all closed or had insufficient data to be included in the second study period.

Interestingly, the two coastal sites west of downtown Los Angeles, Hawthorne and West Los Angeles, behave similarly to the western San Bernardino County sites (Fontana, Upland, and San Bernardino) much farther downwind, exhibiting a mild weekend effect. This is most clearly evident in the principal component plot (Figure 6). A likely explanation is that at the two coastal sites, which experience steady westerly sea breezes during the high ozone season, ozone and precursors are blown downwind rapidly, so the effects of photochemical interactions mainly become visible further downwind.

Between the early period (1992-94) and the later period (1996-98), there are several noticeable changes in weekday-weekend behavior. During 1996-98, after the introduction of reformulated gasoline regulations, mean ozone concentrations decreased substantially on all days, regardless of the day of the week, at virtually all sites. Figure 5 illustrates the change at Azusa. While the Friday to Saturday and Sunday to Monday changes remain significant, many sites begin to exhibit a "Sunday effect", a modest increase from Saturday to Sunday. Some downwind sites, including Azusa, Glendora, and Pomona, show a stronger weekend effect than in 1992-94.

The principal component plot for Los Angeles (Figure 6) graphically displays the patterns discussed above. The first principal component (PC 1) is an indicator of the overall weekend effect. Sites further to the right in the plot show a stronger weekend effect, those to the left, a relatively weak effect. The second principal component (PC 2) represents a Sunday effect, or Saturday-to-Sunday increase, superimposed on the overall weekend effect. The general upward migration along the PC 2 axis, going from the first period to the second, shows that many sites experience a stronger Sunday effect during the second period than in the first.

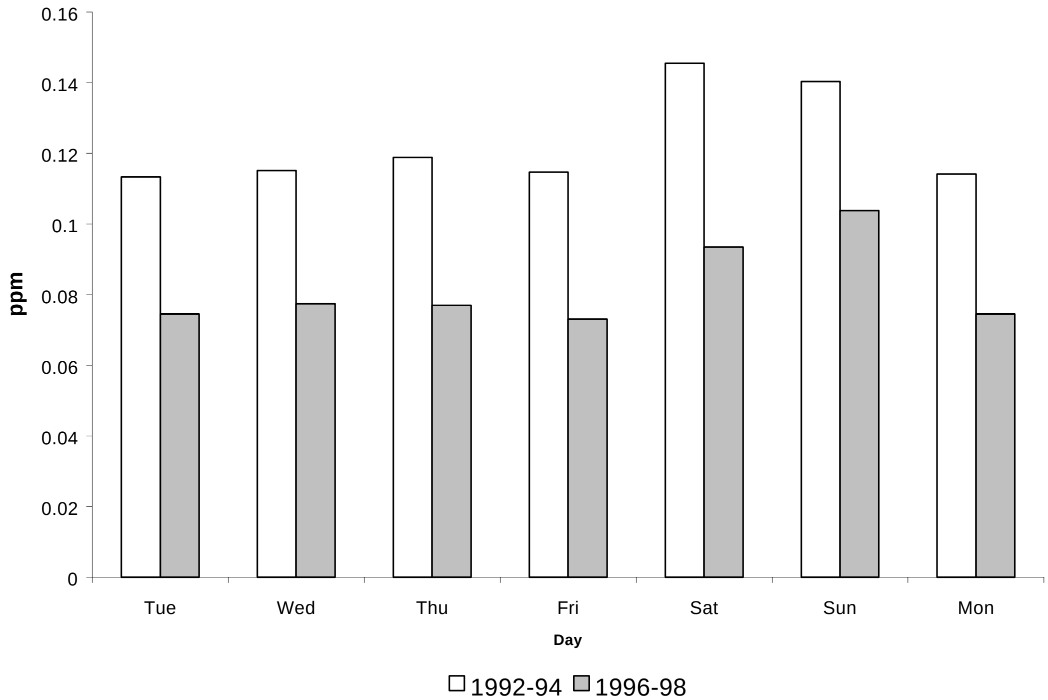

Figure 5: Mean peak ozone by day of week at Azusa.

4.2 San Francisco Bay Area

During 1992-95, the typical pattern of the weekend ozone behavior is similar to that in Los Angeles: a large increase from Friday to Saturday, no change or small decrease from Saturday to Sunday, and a large decrease from Sunday to Monday. This weekend behavior is strongly evident at a cluster of urban sites including Oakland, San Leandro, and San Jose-4th Street (SJ 4th). As in Los Angeles, the transport sites far downwind show a milder weekend effect; the changes from Friday to Saturday and Sunday to Monday are not significant at the 95% level.

After the introduction of CBG, peak ozone concentrations dropped on all days of the week during 1996-98. The weekend effect becomes stronger at the three urban sites, but it remains largely unchanged at other sites. Many sites begin to exhibit a Sunday effect; all sites show a larger increase (or smaller decrease) from Saturday to Sunday in the later period. The principal component plot for the San Francisco Bay Area (Figure 7) shows these tendencies clearly.

As in Los Angeles, far downwind sites in the San Francisco Bay Area do not show any significant day-to-day changes in ozone behavior. For example, at Bethel Island, Fairfield, and Napa, peak ozone does not change significantly during the weekend in either period.

4.3 Sacramento

The results for Sacramento are less conclusive, partly due to lack of data. During 1992-95, two far downwind sites, Auburn and Folsom, behave like the downwind sites in Los Angeles and the San Francisco Bay Area. The lone downtown site, Sacramento-T Street (Sac T St), shows ozone behavior similar to the downtown sites in Los Angeles (see Figure 8). Note that the increase from Friday to Saturday is significant only at three sites: North Highlands, Sacramento-Del Paso Manor (Sac DP), and Sacramento-T Street. At several sites, peak ozone actually increased slightly from Sunday to Monday. These sites are distinguished by an increase in peak ozone from Friday to Saturday, and a decrease from Saturday to Sunday, similar to the far downwind sites in Los Angeles during 1992-94.

In Sacramento, the roles of the first two principal components are switched, with the first principal component representing the Sunday effect and the second principal component representing an overall weekend effect. This is evident from Table 2.

During 1996-98, peak ozone concentrations dropped on all days of the week. While many sites show ozone increases from Saturday to Sunday, the changes during the week are almost all statistically insignificant.

5 Summary and Conclusions

Generally speaking, in Los Angeles and the San Francisco Bay Area, the typical "weekend effect" behavior (increase on Saturday, flat or small decrease on Sunday, and decrease on Monday) is strongly evident at the downtown sites and less visible at the transport sites far downwind. While most sites exhibit little change from Saturday to Sunday during the earlier period, a Sunday effect (increase from Saturday to Sunday) becomes noticeable in the later period. In the later period, after the implementation of federal RFG and California CBG, ozone concentrations dropped substantially on all days of the week at virtually all sites included in the study. All these patterns are consistent in all the three regions we studied, but results for Sacramento are less conclusive and revealing due to lack of data. One should also note that many of the sites studied displayed a pattern different from the "up on Saturday, flat on Sunday, down on Monday" pattern generally regarded as typical, or failed to exhibit a statistically significant weekend effect.

This study is purely descriptive, motivated by a desire to reduce a huge volume of data on ozone concentrations, spanning most of California and the better part of a decade, to a meaningful set of summary statistics and some useful broad qualitative conclusions. It is not our intention to provide definitive information with respect to the benefit or disbenefit of control strategies. To make accurate judgements about causes and underlying mechanisms will require a careful approach which takes precursor concentrations, meteorology, and diurnal patterns explicitly into account. We hope that the information presented in this study will yield insight into fruitful directions for further research on causation and provide facts against which to test possible explanations.

Acknowledgements

The authors would like to thank Lawrence Larsen, and Bart Croes, of the Air Resources Board, and Dr. Robert Shumway, of the University of California, Davis, for their valuable input and suggestions.

Table 1. Results of principal component analysis on robust mean differences for the three basins studied. Tabulated values are component loadings; for example,

PC1 = 0.44 Sat-Fri + 0.44 Sun-Sat – 0.78 Mon-Sun

Los Angeles

	PC1	**PC2**	**PC3**
Sat-Fri	0.44	-0.65	0.62
Sun-Sat	0.44	0.76	0.48
Mon-Sun	-0.78	< 0.1	0.62
Variance explained	82%	16%	2%

San Francisco Bay Area

	PC1	**PC2**	**PC3**
Sat-Fri	0.65	-0.31	0.70
Sun-Sat	0.26	0.95	0.18
Mon-Sun	-0.72	< 0.1	0.70
Variance explained	66%	28%	6%

Sacramento

	PC1	**PC2**	**PC3**
Sat-Fri	< 0.1	0.49	0.87
Sun-Sat	0.99	0.11	< 0.1
Mon-Sun	< 0.1	-0.87	0.49
Variance explained	54%	34%	11%

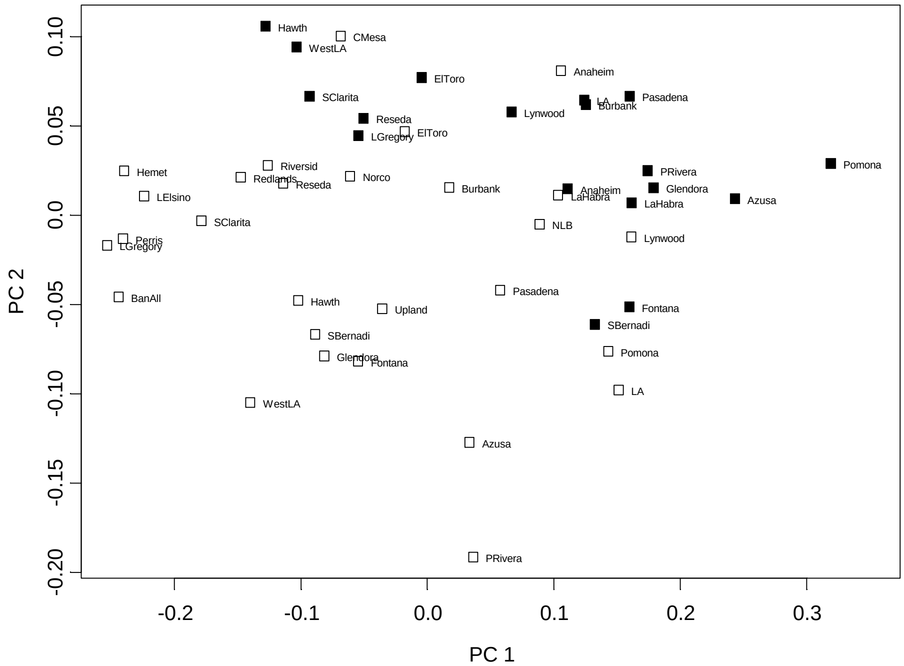

Figure 6: Principal component plot for Los Angeles.
Hollow markers: 1992-94; Solid markers: 1996-98.

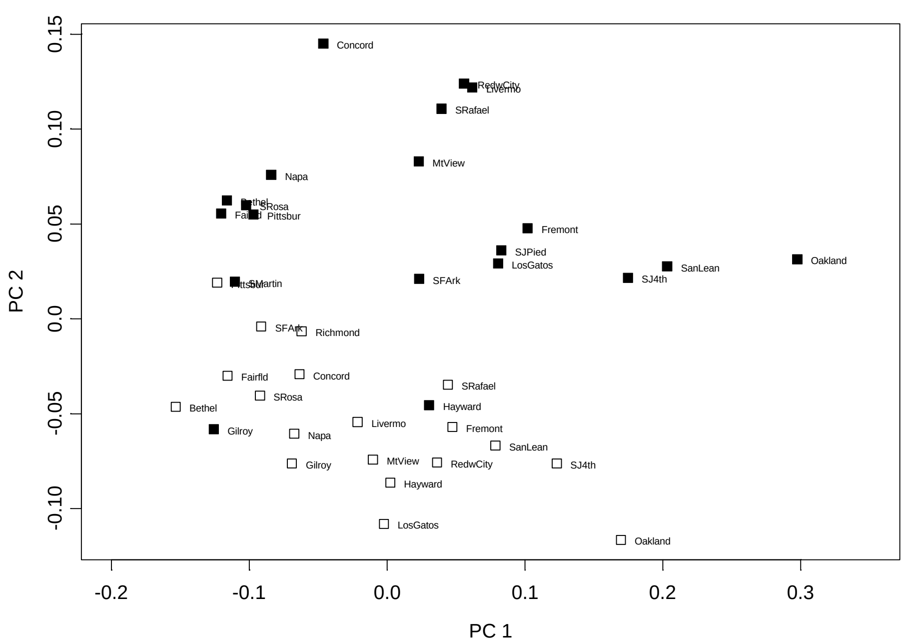

Figure 7: Principal component plot for the San Francisco Bay Area.
Hollow markers: 1992-95; Solid markers: 1996-98.

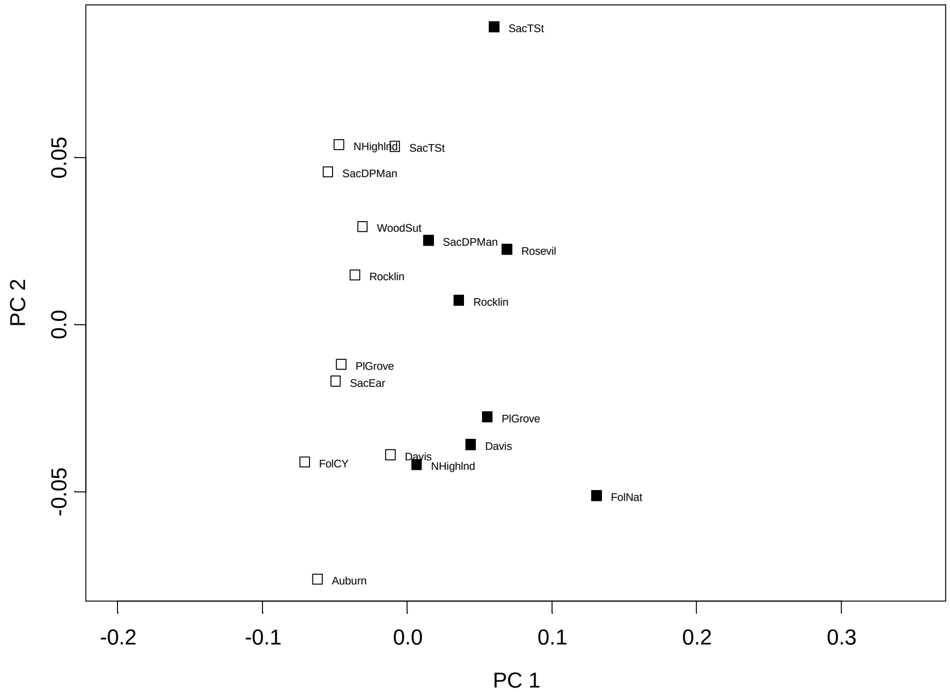

Figure 8: Principal component plot for Sacramento.
Hollow markers: 1992-95; Solid markers: 1996-98.

Table 2. Absolute and percent day to day changes by site, basin, period

Sacramento, 1992-95

Site	Mean of Fri max O3 (ppm)	Percent change Sat-Fri	Sun-Sat	Mon-Sun	Absolute difference (ppm) Sat-Fri	Sun-Sat	Mon-Sun	Test for significance (Y = significant at 95%) Sat-Fri	Sun-Sat	Mon-Sun
Auburn	0.079	-1%	-8%	6%	0.000	-0.006	0.004			
Davis	0.062	2%	-3%	3%	0.001	-0.002	0.002			
Folsom CY	0.075	5%	-8%	4%	0.003	-0.006	0.003			
N. Highlands	0.063	8%	-5%	-4%	0.005	-0.003	-0.003	Y		
Pl. Grove	0.064	6%	-6%	2%	0.004	-0.004	0.001			
Rocklin	0.073	5%	-4%	-2%	0.004	-0.003	-0.001			
Sac DP	0.069	10%	-6%	-2%	0.007	-0.004	-0.002	Y		
Sac Earhart	0.066	4%	-6%	2%	0.003	-0.004	0.001			
Sac T St	0.059	10%	-1%	-3%	0.006	-0.001	-0.002	Y		
Woodland	0.061	3%	-4%	-4%	0.002	-0.002	-0.003			

1996-98

Site	Mean of Fri max O3 (ppm)	Percent change Sat-Fri	Sun-Sat	Mon-Sun	Absolute difference (ppm) Sat-Fri	Sun-Sat	Mon-Sun	Test for significance Sat-Fri	Sun-Sat	Mon-Sun
Davis	0.057	-1%	3%	2%	-0.001	0.002	0.001			
Folsom Nat.	0.063	6%	12%	9%	0.004	0.008	0.007		Y	
N. Highlands	0.057	4%	-1%	5%	0.002	-0.001	0.003			
Pl. Grove	0.058	1%	4%	2%	0.000	0.002	0.001			
Rocklin	0.063	5%	3%	0%	0.003	0.002	0.000			
Roseville	0.062	3%	6%	-2%	0.002	0.004	-0.001			
Sac DP	0.058	4%	1%	-2%	0.003	0.000	-0.001			
Sac T St	0.054	8%	6%	-7%	0.004	0.004	-0.004			

Los Angeles, 1992-94

Site	Mean of Fri max O3 (ppm)	Percent change Sat-Fri	Percent change Sun-Sat	Percent change Mon-Sun	Absolute difference (ppm) Sat-Fri	Absolute difference (ppm) Sun-Sat	Absolute difference (ppm) Mon-Sun	Test for significance (Y = significant at 95%) Sat-Fri	Test for significance Sun-Sat	Test for significance Mon-Sun
Anaheim	0.066	12%	12%	-26%	0.008	0.009	-0.022	Y		Y
Azusa	0.115	29%	-5%	-20%	0.034	-0.007	-0.028	Y		Y
Banning	0.085	8%	-11%	0%	0.007	-0.010	0.000			
Burbank	0.087	13%	3%	-21%	0.012	0.003	-0.021	Y		Y
Costa Mesa	0.052	5%	7%	-13%	0.003	0.004	-0.008			Y
El Toro	0.063	11%	5%	-17%	0.007	0.004	-0.012	Y		Y
Fontana	0.119	21%	-5%	-14%	0.025	-0.007	-0.019	Y		Y
Glendora	0.132	18%	-6%	-13%	0.024	-0.010	-0.018	Y		Y
Hawthorne	0.054	16%	-4%	-10%	0.009	-0.003	-0.006	Y		Y
Hemet	0.083	2%	-6%	-1%	0.002	-0.005	-0.001			
LA	0.073	31%	1%	-28%	0.023	0.001	-0.027	Y		Y
La Habra	0.075	20%	8%	-25%	0.015	0.007	-0.024	Y		Y
Lk. Elsinore	0.092	6%	-5%	-1%	0.005	-0.005	-0.001			
Lk. Gregory	0.132	8%	-7%	3%	0.010	-0.011	0.004			
Lynwood	0.046	24%	8%	-28%	0.011	0.005	-0.017	Y		Y
NLB	0.054	18%	4%	-25%	0.010	0.003	-0.017	Y		Y
Norco	0.084	11%	1%	-14%	0.009	0.001	-0.013	Y		Y
Pasadena	0.101	24%	3%	-21%	0.024	0.003	-0.027	Y		Y
Perris	0.115	6%	-8%	0%	0.007	-0.010	0.000			
Pomona	0.101	29%	3%	-27%	0.030	0.004	-0.037	Y		Y
Pico Rivera	0.092	33%	-10%	-21%	0.030	-0.012	-0.023	Y		Y
Redlands	0.128	7%	-2%	-7%	0.010	-0.003	-0.010			Y
Reseda	0.087	9%	-1%	-10%	0.008	-0.001	-0.009	Y		Y
Riverside	0.118	8%	0%	-9%	0.010	-0.001	-0.011			Y
S. Bernadino	0.121	17%	-6%	-12%	0.021	-0.008	-0.016	Y		Y
Sta. Clarita	0.107	10%	-4%	-4%	0.010	-0.005	-0.004	Y		
Upland	0.118	19%	-3%	-15%	0.022	-0.004	-0.021	Y		Y
West LA	0.066	16%	-11%	-9%	0.011	-0.009	-0.006	Y		Y
1996-98										
Anaheim	0.047	24%	11%	-23%	0.011	0.007	-0.015	Y		Y
Azusa	0.073	31%	17%	-31%	0.022	0.016	-0.034	Y	Y	Y
Burbank	0.066	20%	15%	-24%	0.013	0.012	-0.022	Y	Y	Y
El Toro	0.058	11%	9%	-16%	0.007	0.006	-0.012	Y		Y
Fontana	0.084	29%	6%	-28%	0.024	0.006	-0.032	Y		Y
Glendora	0.085	26%	14%	-27%	0.022	0.014	-0.033	Y	Y	Y
Hawthorne	0.055	1%	4%	-10%	0.000	0.002	-0.006			Y
LA	0.056	20%	16%	-23%	0.011	0.011	-0.018	Y	Y	Y
La Habra	0.054	26%	12%	-26%	0.014	0.008	-0.020	Y		Y
Lk. Gregory	0.103	11%	4%	-13%	0.012	0.005	-0.016	Y		Y
Lynwood	0.039	14%	10%	-22%	0.006	0.004	-0.011	Y		Y
Pasadena	0.070	20%	17%	-27%	0.014	0.014	-0.026	Y	Y	Y
Pomona	0.064	33%	22%	-35%	0.021	0.019	-0.036	Y	Y	Y
Pico Rivera	0.063	25%	14%	-27%	0.016	0.011	-0.024	Y	Y	Y
Reseda	0.071	11%	6%	-13%	0.008	0.005	-0.011	Y		Y
S. Bernadino	0.091	29%	5%	-25%	0.027	0.006	-0.031	Y		Y
Sta. Clarita	0.082	7%	4%	-11%	0.006	0.003	-0.010			Y
West LA	0.057	6%	6%	-9%	0.003	0.004	-0.006			Y

San Francisco Bay Area, 1992-95

Site	Mean of Fri max O3 (ppm)	Percent change			Absolute difference (ppm)			Test for significance (Y = significant at 95%)		
		Sat-Fri	Sun-Sat	Mon-Sun	Sat-Fri	Sun-Sat	Mon-Sun	Sat-Fri	Sun-Sat	Mon-Sun
Bethel Is.	0.057	5%	-4%	-1%	0.003	-0.003	0.000			
Concord	0.053	9%	-1%	-9%	0.005	-0.001	-0.005	Y		
Fairfield	0.051	7%	-2%	-4%	0.003	-0.001	-0.002			
Fremont	0.049	16%	-1%	-17%	0.008	-0.001	-0.010	Y		Y
Gilroy	0.059	12%	-5%	-7%	0.007	-0.003	-0.004	Y		
Hayward	0.038	16%	-5%	-13%	0.006	-0.002	-0.006	Y		Y
Livermore	0.058	13%	-2%	-12%	0.007	-0.002	-0.007	Y		Y
Los Gatos	0.050	18%	-6%	-11%	0.009	-0.004	-0.006	Y		Y
Mtn. View	0.041	14%	-4%	-13%	0.006	-0.002	-0.006	Y		Y
Napa	0.047	7%	-5%	-11%	0.003	-0.002	-0.005			Y
Oakland	0.026	31%	-3%	-23%	0.008	-0.001	-0.007	Y		Y
Pittsburg	0.059	1%	1%	-6%	0.001	0.001	-0.004			
Redwood C.	0.035	17%	-3%	-16%	0.006	-0.001	-0.006	Y		Y
Richmond	0.038	7%	1%	-10%	0.003	0.000	-0.004			Y
San Leandro	0.042	18%	-2%	-20%	0.007	-0.001	-0.010	Y		Y
S. Francisco	0.029	8%	1%	-6%	0.002	0.000	-0.002			
SJ 4^{th} St.	0.047	25%	-1%	-20%	0.012	0.000	-0.012	Y		Y
S. Rafael	0.034	14%	1%	-18%	0.005	0.000	-0.007	Y		Y
S. Rosa	0.039	8%	-3%	-6%	0.003	-0.001	-0.002	Y		

1996-98

Site	Mean of Fri max O3 (ppm)	Percent change			Absolute difference (ppm)			Test for significance (Y = significant at 95%)		
		Sat-Fri	Sun-Sat	Mon-Sun	Sat-Fri	Sun-Sat	Mon-Sun	Sat-Fri	Sun-Sat	Mon-Sun
Bethel Is.	0.046	3%	7%	-4%	0.002	0.003	-0.002			
Concord	0.047	3%	17%	-10%	0.002	0.008	-0.006		Y	
Fairfield	0.043	4%	6%	-3%	0.002	0.003	-0.001			
Fremont	0.035	21%	12%	-17%	0.007	0.005	-0.008	Y		Y
Gilroy	0.050	10%	-4%	0%	0.005	-0.002	0.000			
Hayward	0.036	25%	2%	-8%	0.009	0.001	-0.004	Y		
Livermore	0.048	11%	17%	-17%	0.005	0.009	-0.011		Y	Y
Los Gatos	0.038	23%	10%	-14%	0.009	0.005	-0.007	Y		Y
Mtn. View	0.037	15%	13%	-11%	0.006	0.006	-0.005	Y		
Napa	0.038	3%	9%	-7%	0.001	0.003	-0.003			
Oakland	0.021	37%	15%	-28%	0.008	0.004	-0.009	Y	Y	Y
Pittsburg	0.040	6%	7%	-4%	0.002	0.003	-0.002			
Redwood C.	0.029	10%	17%	-17%	0.003	0.005	-0.006	Y	Y	Y
S. Leandro	0.031	31%	13%	-22%	0.010	0.005	-0.010	Y		Y
S. Francisco	0.026	17%	7%	-11%	0.004	0.002	-0.004	Y		Y
SJ 4^{th} St.	0.038	28%	11%	-21%	0.011	0.005	-0.011	Y		Y
SJ Piedmont	0.036	20%	10%	-15%	0.007	0.004	-0.007	Y		Y
S. Martin	0.051	10%	4%	0%	0.005	0.002	0.000			
S. Rafael	0.028	12%	16%	-14%	0.003	0.005	-0.005	Y	Y	Y
S. Rosa	0.033	6%	7%	-4%	0.002	0.002	-0.001			

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